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(54) Title: HIGH CONTRAST FRONT AND REAR VIEWING SURFACES FOR PROJECTION DISPLAYS (57) Abstract A viewing surface capable of high contrast and high resolution comprising one or more materials that preferentially reflect or transmit or scatter monochromatic light at the primary wavelengths necessary to generate the color gamut appropriate for a given display application. A viewing surface capable of high contrast and high resolution comprising one or more materials which can include rare earth ions, etc. and may be combined with absorbing substrates and/or interference filters.		

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HIGH CONTRAST FRONT AND REAR VIEWING SURFACES FOR PROJECTION DISPLAYS

5

Field of the Invention:

10 The present invention relates to a high contrast front and rear viewing screen suitable for projection displays.

Background of the Invention:

15 The contrast in projection displays is limited by the amount of ambient light impinging on the viewing surface. This problem is acute in a front projection display which projects an image onto a conventional diffusing surface. The viewing screen must be highly reflective due to the relatively low light levels generated by common projection technology. In addition, current projection techniques generate non-saturated colors requiring a surface that can reflect
20 across a broad spectral band. As a result, these screens reflect the ambient light equally as well as the projected light from the display. The darkest screen color is white when any appreciable room light is present.

25 In order to generate high contrast images, the projector must generate sufficiently high light levels so that the viewer can perceive the projected image above the ambient light levels. Most projectors cannot currently meet this requirement. Generating high contrast,

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sufficiently bright images using front projection techniques has not yet been adequately solved.

The most common solution is to turn the room lights off. However, this solution is usually not acceptable in, for example, educational and training meetings. Several methods have been developed to solve this contrast problem. One method employs a rear projection screen. Several designs exist which enable the viewing screen to function as an optical diode. In this case, the projected image is transmitted through the viewing surface while the ambient light is absorbed by the screen or transmitted through the screen. These devices greatly improve the contrast and remain the preferred embodiment for projection displays.

This optical diode effect is the basis of the standard screens used in rear projection televisions. These screens employ a lenticular lens element located directly behind a mask of horizontal black stripes. The absorbing regions are separated only by a small gap. The lenticular lens focuses the projected image generated from behind the screen through the gaps towards the viewer. However, the ambient light impinging from the front is absorbed by the black stripes. The small fraction of ambient light transmitted through the gaps is absorbed by the blackened walls of the projector's cabinet.

The common optical diode screens have several limitations. The obtainable contrast is still below the level that is required, particularly in high ambient light conditions as in an office environment. In addition, most diodes employ fixed structures and optics as discussed above. These surfaces lead to moire patterns and limit the obtainable resolution. No spatial frequencies can be displayed which have a higher frequency than the periodic pattern of the structure.

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Summary of the Invention:

One approach to improve contrast and resolution is to take advantage of the light emission characteristics offered by the new projection techniques based on lasers or resonant microcavities. The latter is described in U.S. Patent No. 5,469,018. These light sources generate narrow band emission, resulting in highly saturated primary colors. In contrast, common light valves and projection CRTs generally produce non- monochromatic light. Any spectral filtering employed to increase saturation limits the brightness and lowers the contrast.

Viewing screens can be fabricated to generate high contrast images when the image sources emit monochromatic light. In a front viewing screen application, such surfaces can be made to preferentially reflect the projected light while absorbing the ambient light. In a rear viewing screen application, such surfaces can be made to transmit the projected image while absorbing the ambient light.

Accordingly, the invention includes a viewing surface capable of high contrast and high resolution comprising one or more materials that preferentially reflect or transmit or scatter monochromatic light at the primary wavelengths necessary to generate the color gamut appropriate for a given display application.

Further, the invention includes a viewing surface capable of high contrast and high resolution comprising one or more materials which can include rare earth ions, etc. and may be combined with absorbing substrates and/or interference filters.

Other objects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiments, when read in light of the accompanying drawings.

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Brief Description of the Figures:

Fig. 1 is an embodiment of the invention of a front projection diffusing surface laminated to AR coated wavelength selective optical filter glass consisting of wavelength selective material (WSM).

5 Fig. 2 is an embodiment of the invention of a rear projection diffusing surface laminated to AR coated wavelength selective optical filter glass consisting of wavelength selective material (WSM).

Fig. 3 is an embodiment of the invention of a front projection diffusing surface laminated to an interference filter.

10 Fig. 4 is an embodiment of the invention of a rear projection diffusing surface laminated to an interference filter.

Fig. 5 is an embodiment of the invention of a front projection diffusing surface laminated to optical filter glass consisting of wavelength selective material and interference coating.

15 Fig. 6 is an embodiment of the invention of a rear projection diffusing surface laminated to optical filter glass consisting of wavelength selective material and interference coating.

Fig. 7 is an embodiment of the invention of a front projection diffusing surface fabricated from wavelength selective scattering elements.

Fig. 8 is an embodiment of the invention of a rear projection diffusing surface fabricated from wavelength selective scattering elements.

Fig. 9 is an embodiment of the invention of a front projection diffusing surface overcoated with wavelength selective paint.

25 Fig. 10 is an embodiment of the invention of a rear projection diffusing surface overcoated with wavelength selective paint.

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Fig. 11 is a spectral transmittance of a commercially available contrast enhancement filter.

Detailed Description of the Preferred Embodiment:

5 A diffuse viewing surface typically involves an array of small features or elements designed to distribute the projected light into a specific angular range. This surface may be attached to a rigid or flexible substrate. The resultant light distribution is governed by the refractive indices of the materials involved along with the form and
10 size of the elements. Scattering, refraction, diffraction and reflection may all be utilized to generate the desired light distribution. The elements may be randomly placed or may form lenticular or fresnel optical structures. Parameters of the screen are optimized so that the resulting light distribution is appropriate for the viewing area. The
15 feature density and size also determines the obtainable spatial resolution. High definition images require relatively fine features in order to adequately display the image.

 In the preferred embodiment of the invention, a suitable wavelength selective optical filter consisting of a wavelength selected
20 material (WSM) is attached to the viewing side of a diffuse viewing surface. As illustrated in Figs. 1 and 2, the screen may be used for either front or rear projection. The optical filter is designed to substantially transmit the three primary colors generated by a projector utilizing resonant microcavities, lasers or other narrow band sources
25 of light while substantially blocking any broadband ambient light.

 One optical filter material suitable for this application is Schott glass filter S-8807. Its transmittance spectrum is provided in Figure 11. The spectrum contains highly transmitting regions located around

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the primary colors: red (625 nm), green (550 nm) and blue (475 nm). The majority of the remaining visible spectral regions are absorbed. Similar Schott glass filters such as S8806A and S8801 may also be utilized. Filters using other wavelength selective materials may also be
5 used. Materials containing rare earth ions represent an excellent choice due to their narrow absorption features. Other potential materials may utilize transition metal ions or organic dyes to generate narrow absorption features.

The front of the wavelength selective optical filter may be anti-
10 reflection coated to further enhance image contrast. Any of the several methods commercially utilized for anti- reflection coating display glass may be used. These methods include but are not limited to the application of a thin film layer, or layers, of refractive index intermediate between the index of air and the index of the optical filter
15 (see J. A. Dobrowolski, *Optical Properties of films and Coatings*, in *Handbook of Optics Vol. I, Fundamentals, Techniques, and Design*, McGraw-Hill, Inc., 1995; which is incorporated herein by reference) and the roughening of the front reflecting surface.

Another wavelength selective optical filter that preferentially
20 transmits monochromatic light is an interference filter. Embodiments utilizing interference filters are illustrated in Figs. 3 and 4. It is possible to design a filter or collection of filters that reflect or transmit multiple wavelengths such as the three primary colors produced by the projector (examples of such filters can be found in: J. A. Dobrowolski,
25 *Optical Properties of Films and Coatings*, in *Handbook of Optics Vol. I, Fundamentals, Techniques, and Design*, McGraw-Hill, Inc., 1995; E. Pelletier and H.A. Macleod, *Interference Filters with Multiple Peaks*, vol. 72, no. 6, J.Opt.Soc.Am/, June 1982; L. Young, *Multilayer*

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Interference Filters with Narrow Stop Bands, vol. 6, no. 2, Applied Optics, February 1967; U.S. Patent No. 3,759,604; all of which are incorporated herein by reference). These filters may be combined with a diffuse viewing surface to obtain the appropriate light distribution.

5 Diffuse viewing surfaces can include typical and existing rear and front projection screens. One method for generating absorption of undesired wavelengths may be the use of an induced transmission filter or filters (see P. H. Lissberger, *Coatings with Induced Transmission*, vol. 20, no. 1, Applied Optics, January 1, 1981, which is incorporated herein by

10 reference) tuned to pass the primary colors. A suitable wavelength selective optical filter may also be constructed as a combination of an interference filter and wavelength selective material as illustrated in Figs 5 and 6. Interference filters are typically both wavelength and angle specific. Filters suitable for this application will need to be

15 designed to function properly over the range of angles required for viewing.

In another embodiment, the high contrast screen can be made by employing individual elements which inherently scatter, reflect, diffract, refract or transmit only the narrow wavelength regions

20 corresponding to the three primary display colors as illustrated in Figs. 7 and 8. The elements may be randomly placed or may form lenticular or fresnel optical structures. These elements when combined form a diffuse viewing surface that distributes light that matches the desired wavelengths such as the light generated by a resonant microcavity

25 projection display or a laser projection display. Ambient light would be preferentially absorbed since this light is typically composed of a broad distribution of wavelengths. The individual elements may be constructed from wavelength selective materials or wavelength

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selective structures employing interference or diffraction. The individual elements may involve the Schott filter glasses or interference filters described above.

5 In another embodiment, the wavelength selective material or filter may be applied to the scattering surface as a thin paint or powder layer rather than as a freestanding structure as shown in Figs. 9 and 10. For this embodiment, such WSM material can be ground up and included in an emulsion and then applied to a surface.

10 A viewing surface based upon individual wavelength selective elements can be made using standard techniques employed to fabricate current screens. The size and form of the elements would be selected to generate the correct angular distribution while maintaining sufficient spatial resolution.

15 **Industrial Applicability:**

High contrast viewing screens capable of high resolution are possible when combined with a projection display that generates nearly monochromatic light. These viewing surfaces will be used in front and rear projection systems. Such applications include television, home theatres and conference rooms.

Other features, aspects and objects of the invention can be obtained from a review of the figures.

It is to be understood that other embodiments of the invention can be developed and fall within the spirit and scope of the invention.

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We claim:

1. A viewing screen comprising:
a screen which preferentially selects light from a substantially
5 monochromatic source; and
said screen absorbing ambient light.
2. The viewing screen of claim 1 wherein:
said screen a front viewing screen and said screen preferentially
10 reflects light from a substantially monochromatic source while
absorbing ambient light.
3. The viewing screen of claim 1 wherein:
said screen is a rear viewing screen and screen preferentially
15 transmits light from a substantially monochromatic source while
absorbing ambient light.
4. The viewing screen of claim 2 wherein:
said screen includes at least three materials, each of said
20 materials for preferentially reflecting light from a different substantially
monochromatic light source.
5. The viewing screen of claim 3 wherein:
said screen includes at least three materials, each of said
25 materials for preferentially reflecting light from a different substantially
monochromatic light source.

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6. The viewing screen of claim 1 wherein:
said screen includes rare earth ions.

5 7. The viewing screen of claim 1 wherein:
said screen includes light absorbing materials.

8. The viewing screen of claim 1 wherein:
said screen includes interference filters.

10 9. The viewing screen of claim 1 wherein
said screen includes rare earth ions and at least one of
absorbing materials and interference filters.

15 10. The viewing screen of claim 1 wherein:
said screen is a high contrast and a high resolution screen.

11. The viewing screen of claim 1 wherein:
said screen a front viewing screen and said screen preferentially
scatters light from a substantially monochromatic source while
20 absorbing ambient light.

12. The viewing screen of claim 1 wherein:
said viewing screen is one of rigid and flexible.

25 13. The viewing screen of claim 1 wherein:
said viewing screen is comprised of a material having one or
more desired refractive indices.

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14. The viewing screen of claim 1 wherein:
the desired light distribution can be accomplished using at least
one of scattering, refraction, diffraction, and reflection.

5 15. The viewing screen of claim 1 wherein:
said viewing screen can include at least one of randomly placed
structures, lenticular structures, and fresnel structures.

10 16. The viewing screen of claim 1 wherein:
said screen can include materials having selected forms and
sizes.

15 17. The viewing screen of claim 1 wherein
said screen includes at least one wavelength selective optical
filter.

18. The viewing screen of claim 1 wherein:
said screen includes at least one wavelength selected material.

20 19. The viewing screen of claim 1 wherein:
said screen is comprised of a material which at least one of
absorbs and blocks out broadband ambient light.

25 20. The viewing screen of claim 1 wherein:
said viewing screen is comprised of a material with high
transmitting regions around the primary colors of red at about 625 nm,
green at about 550nm, and blue at about 475nm.

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21. The viewing screen of claim 1 wherein:
said screen includes one of transition metal ions and organic
dyes.

5 22. The viewing screen of claim 1 wherein:
said screen includes an anti-reflective coating.

23. The viewing screen of claim 1 wherein:
said screen is comprised of at least one interference filter that
10 at least one of reflects and transmits at least one selected wavelength
of light.

24. The viewing screen of claim 1 wherein:
said screen includes a filter and a diffuse viewing surface.

15 25. The viewing screen of claim 1 wherein:
said screen includes an induced transmission filter tuned to pass
at least one color.

20 26. The screen of claim 1 wherein:
said screen includes an interference filter and a wavelength
selected material.

25 27. The screen of claim 1 wherein:
said screen is comprised of a paint.

28. The screen of claim 1 wherein:
said screen is comprised of a powder deposited on a substrate.

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29. The screen of claim 1 including:
a first diffusing layer;
a second wavelength selective material layer; and
a third anti-reflective layer.

5

30. The screen of claim 1 including:
a first diffusing layer; and
a second interference filter layer.

10

31. The screen of claim 1 including:
a first diffusing layer;
a second wavelength selective material layer; and
a third interference filter layer.

15

32. The screen of claim 1 including:
a diffusing layer comprised of wavelength selective scattering
elements.

20

33. The screen of claim 1 including:
a diffusing layer coated with wavelength selective paint.

25

34. A viewing screen comprising:
a screen which preferentially selects radiation from a
substantially monochromatic source; and
said screen absorbing ambient radiation.

35. A viewing screen comprising:
a screen including at least one wavelength selective material.

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36. The screen of claim 35 wherein:

said screen is comprised of a wavelength selective material that can select a first primary color of substantially a single first wavelength;

5 said screen is comprised of a wavelength selective material that can select a second primary color of substantially a single second wavelength; and

10 said screen is comprised of a wavelength selective material that can select a third primary color of substantially a single third wavelength.

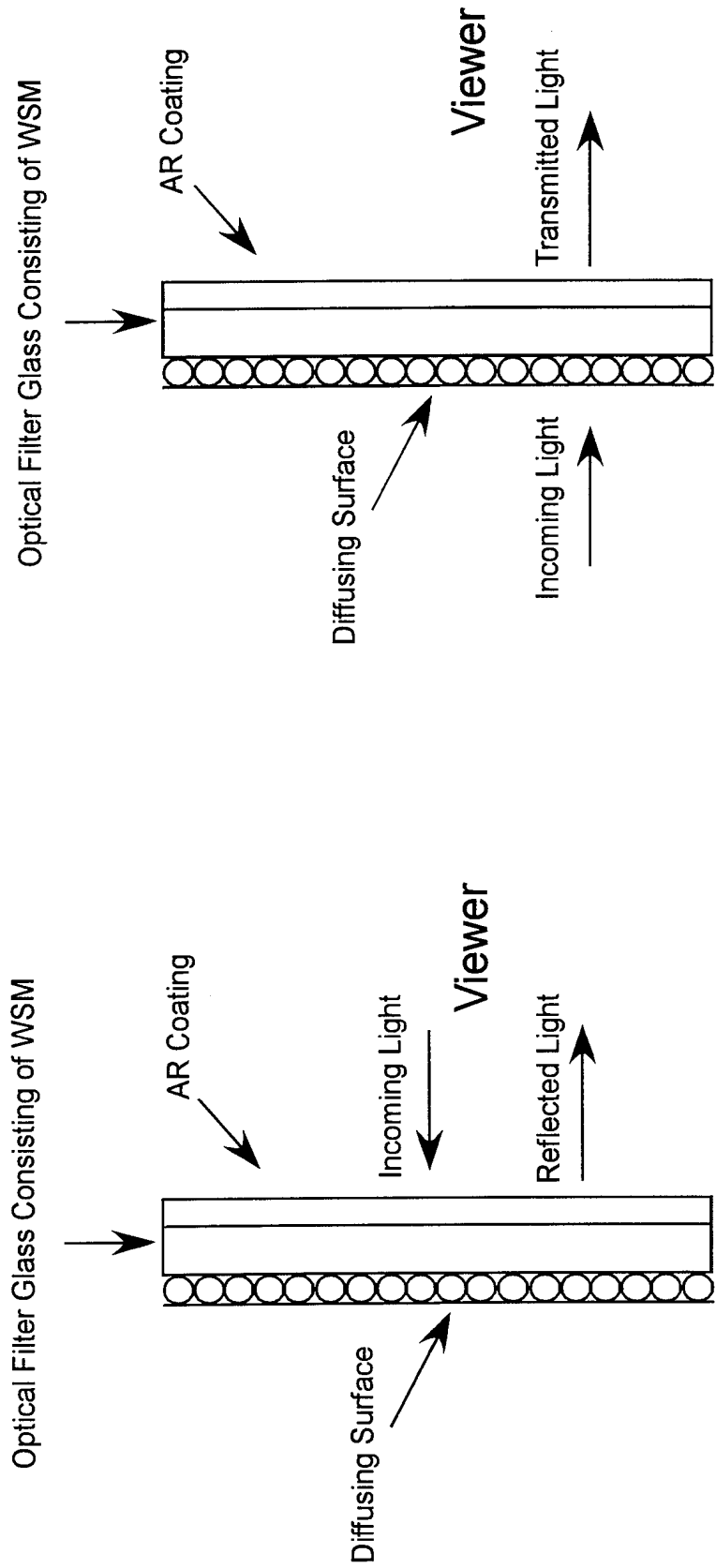


Fig. 1

Fig. 2

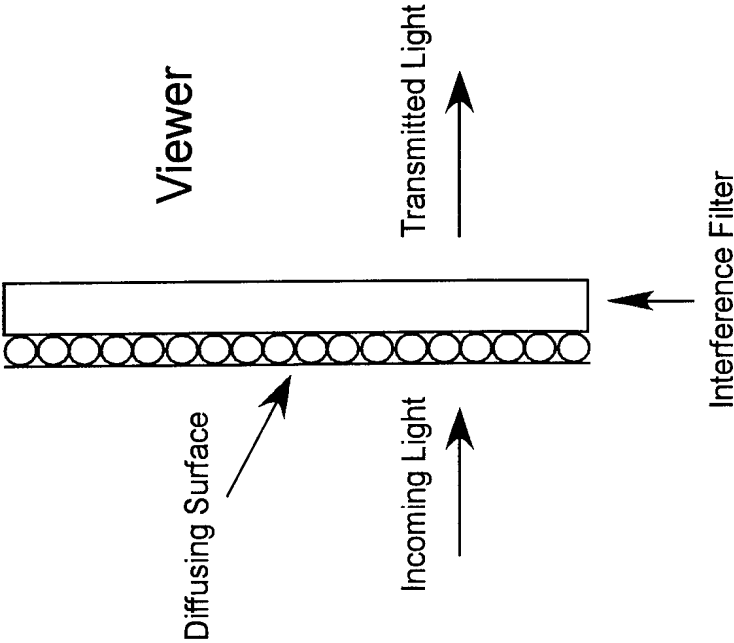


Fig. 4

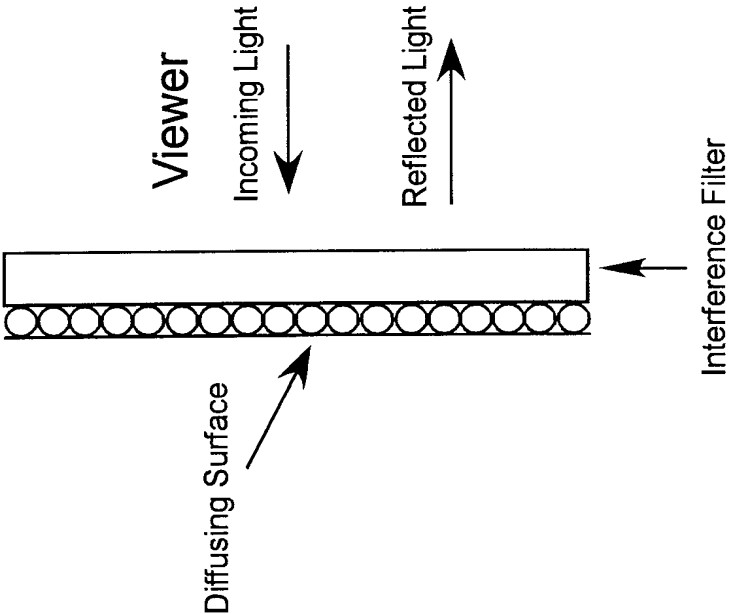


Fig. 3

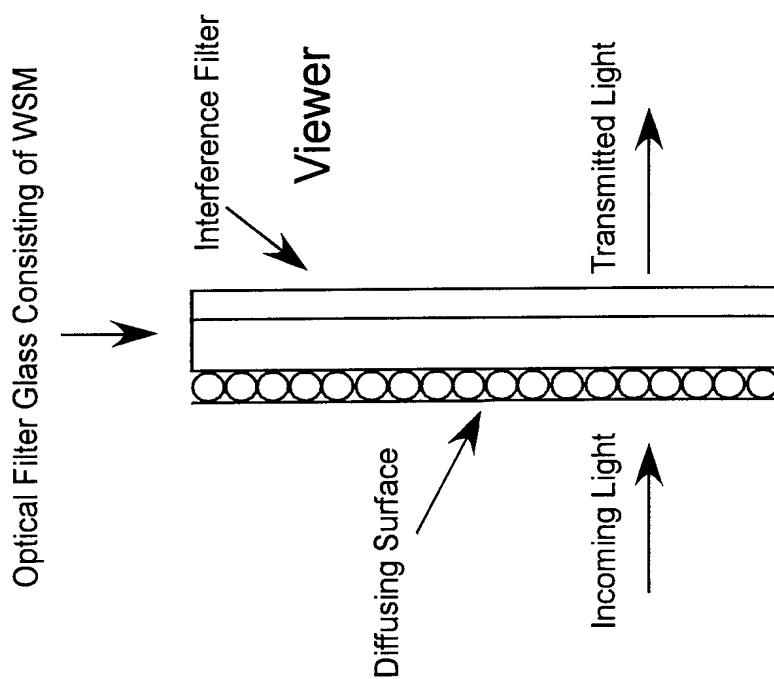


Fig. 6

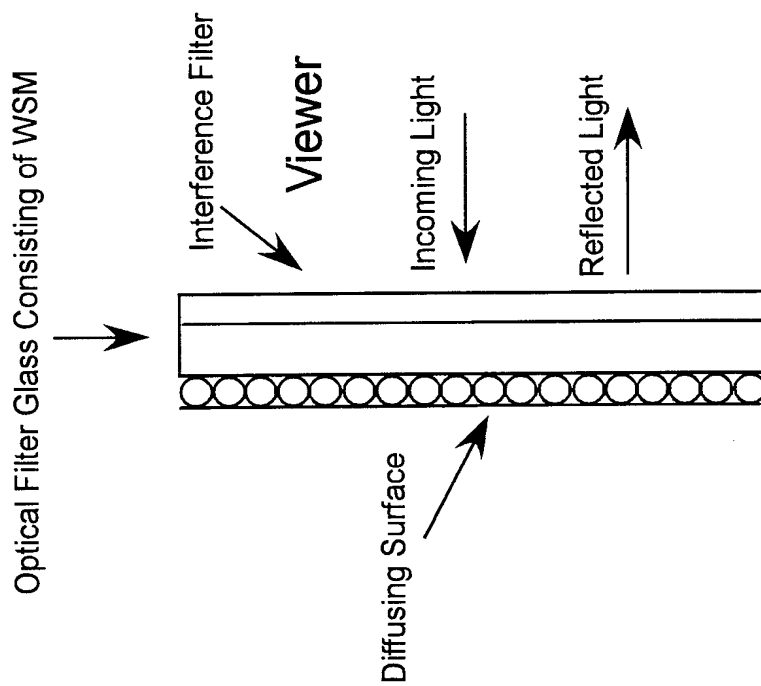


Fig. 5

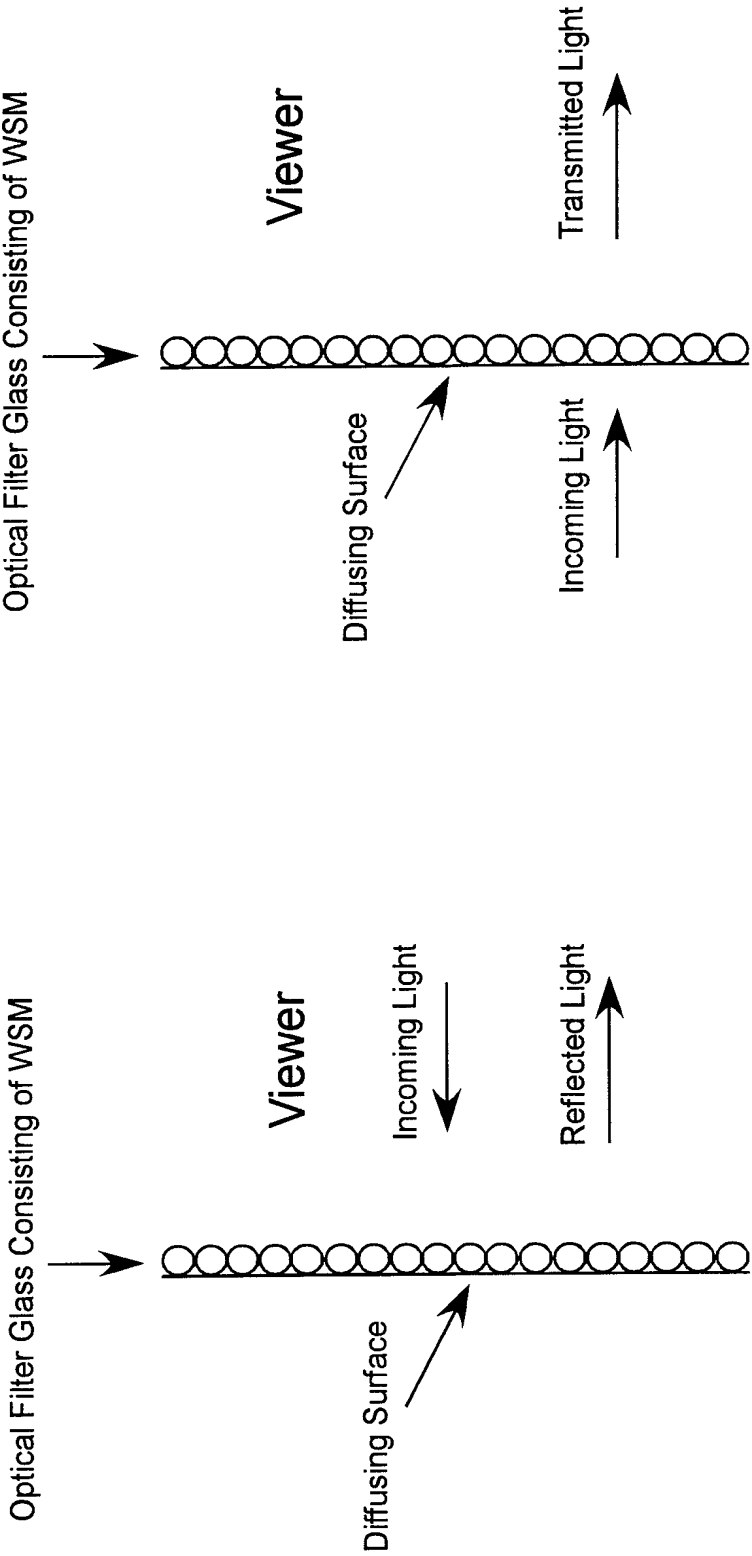


Fig. 8

Fig. 7

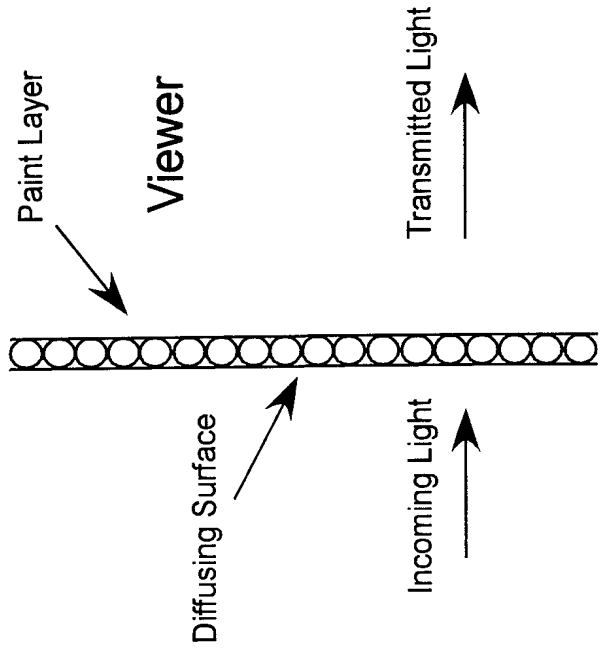


Fig. 10

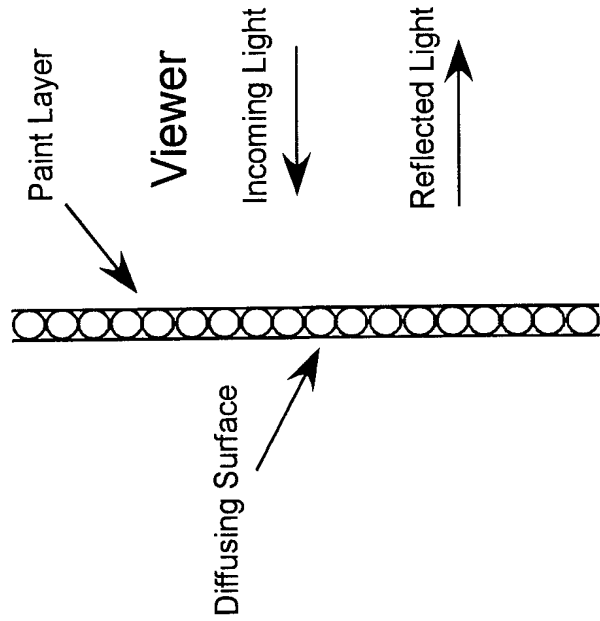
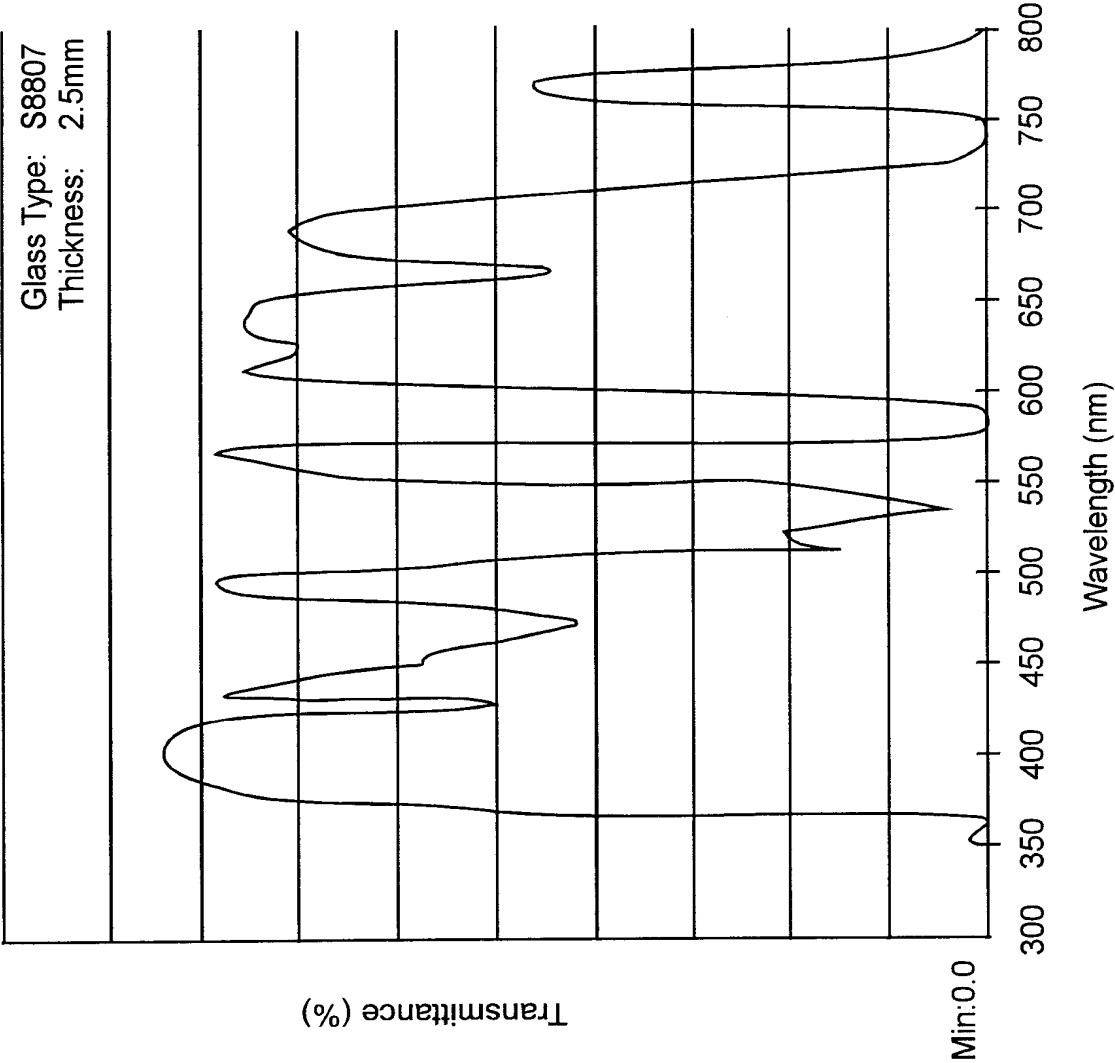


Fig. 9

Fig. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/01816

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G03B 21/56

US CL : 359/443

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/443

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 5,193,015 A (SHANKS) 9 March 1993 (3/9/1993), see entire document especially column 1 line 45-68; column 2, line 1-8; column 2, line 65-column 3, line 21;	1, 2, 4, 5, 7, 8, 10-20, 23-27, 29- 36 ----- 3,9,21,28,22 ----- 6,22



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

30 MARCH 2000

Date of mailing of the international search report

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,003,080 A (MAIMAN et al) 11 January 1977 (1/24/1977), see entire document especially column 3, line 10-50, column 10, line 1-23	3
Y	US 4,713,577 A (GUALTIERI et al) 15 December 1987 (12/15/1987), see entire document especially column 2, line 25-65, column 4, line 55-60	9, 21, 28
Y	US 4,798,994 A (RIJPERS et al) 17 January 1989 (1/17/1989), see entire document especially column 2, line 25-65	22